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1. Your reference	P03869GB	
2. Patent application number *(The Patent Office will fill in this part)*	0304124.1	24 FEB 2003
3. Full name, address and postcode of the or of each applicant *(underline all surnames)*	Charles Raymond LUFFMAN Dorfstrasse 22B 15910 Staakow Germany	
Patents ADP number *(if you know it)*	8497836001	
If the applicant is a corporate body, give the country/state of its incorporation		
4. Title of the invention	AIRCRAFT	
5. Name of your agent *(if you have one)* "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	LAURENCE SHAW & ASSOCIATES 10TH FLOOR METROPOLITAN HOUSE 1 HAGLEY ROAD, EDGBASTON BIRMINGHAM B16 8TG	
Patents ADP number *(if you know it)*	136230002	

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Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

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Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
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b) there is an inventor who is not named as an applicant, or
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Description	27
Claim(s)	3
Abstract	1
Drawing(s)	2

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Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application.

Signature Laurence Shaw & Associates Date 24.02.03

~~LAURENCE SHAW & ASSOCIATES~~

12. Name and daytime telephone number of person to contact in the United Kingdom

LAURENCE SHAW 0121 454 4962

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AIRCRAFT

This invention relates to aircraft suitable for transporting outsized heavy payloads and in particular, although not exclusively, to aircraft that can pick up a load (difficult to transport by road) at a client's site, transit directly without external assistance to another site and then set the load down where wanted without additional infrastructure. To achieve this, the basic requirements are:-

- able to fly autonomously by autopilot signals and/or be manually controlled by a pilot on board;
- takeoff from, or settle to land, at its ground base station plus free flight within its operational ceiling without additional ground infrastructure other than that already existing for conventional aircraft;
- depending on basic size, able to carry a variety of heavy and or large loads, typically: 100, 500 and (as a goal) 1000 tonne or more plus sized typically within a 50 m spherical envelope, in a manner suitable for the purpose (depending on vehicle size developed);
- able to pick up or set down prepared or packaged payloads directly with vertical lift (as a crane);
- operation typically up to 2500 m above sea level (higher for variants);
- continuous free flight operation for periods typically not less than 12 hours – 48 hours as a goal (longer for variants);
- ability to remain typically within 5 m radius of a geostationary position at the payload pickup and set down sites (horizontally and vertically);
- range typically up to 1000 km, depending on fuel provisions – 4000 km as a goal;
- maximum flight speed typically up to 60 knots (111 km/h) as a goal;
- cruise flight speed typically 45 knots (83 km/h);

- able to settle at ground level from free flight or take off from a ground base station (or other suitable sites) essentially unaided;
- able to be moored and held indefinitely at the ground base station;
- able to withstand wind conditions whilst moored up to 60 kts (111 km/h) without damage;
- able to withstand storm conditions whilst moored under gusting winds of 80 kts (148 km/h) without breakaway;
- able to launch or be captured in winds at 50 m above the ground up to 25 kts (46 km/h) – 30 kts (56 km/h) as a goal;
- able to pick up or set down packaged payloads in winds at 100 m above the ground up to 20 kts (37 km/h) – 25 kts (46 km/h) as a goal;
- able to be maintained at the ground station using standard low reach equipment;
- able to be recovered safely to ground level following total power system failure;
- able to be operated from ground station set-ups in locations typically accepted for normal aircraft operation;
- able to be packaged and delivered by road;
- able to be assembled, inflated, set up for operation and maintained at a ground base station mooring site without a hangar;
- able to achieve high utilisation compared with commercial aircraft.

Transport of very large heavy, often indivisible, payloads over land is a significant problem for industrialists who, so far, do not have an easy solution. Even loads that are to be transported by sea must be delivered to the pickup dockyard over land and then later taken from their destination dockyard over land to the delivery address.

Unless rivers or canals are available (unlikely), current over land methods have little option but to employ roads and rails together with the vehicles to move along them. Numerous effectively irremovable obstacles such as bridges, tunnels, pylons and stations or other buildings make such transport of large loads almost impossible. Quite often the terrain or the route through particular areas may also be very difficult to negotiate and there may not be an existing or suitable road or rail system for the transport operation to use.

There is a need to be able to pick up at A, travel directly through the air to B and then set down by a method that has no obstacles and is cost effective – perhaps similar to transport by ship.

There are three categories of aircraft relevant to the present invention:

- Heavier-than-air (HTA) vehicles,
- Lighter-than-air (LTA) vehicles,
- Hybrid vehicles.

HTA vehicles primarily utilise aerodynamic methods to generate lift, which necessitates movement of an aerofoil or lifting body shape through the air, whilst LTA vehicles mainly utilise aerostatic lift methods. Hybrids may use both, and be of non-conventional form. Thrust from propulsive units also may be used for lifting purposes and this generally has been applied before to each category, typically with vector mechanisms to orientate the thrust direction.

The reason that perhaps a successful vehicle able to meet the above basic requirements has not already emerged is that it is extremely difficult to do, particularly

in the light of established airworthiness standards and practices, which need compliance.

Clearly the fuel, structure, systems, crew and other disposable loads must be drastically minimised to maximise the potential for payload carrying ability. The aircraft itself also will be very big compared with existing or previous aircraft already produced. Because of the difficulty to lift very heavy outsized and essentially indivisible loads, a hybrid aircraft that utilises both aerodynamic and aerostatic methods to the fullest extent for lift generation appears to be most suitable to perform the task. Also, to make the system viable as a commercial product, it must be cost effective (compared with normal aircraft) and be able to operate with minimum ground infrastructure requirements.

When considering how to generate sufficient lift using a propeller or rotor blade system similar to a helicopter rotor head, the following aspects were deduced:-.

- Lift along the blade varies unless the blade's pitch is varied to compensate
- Rotational speed is limited by sonic conditions at the outer tip
- A central or core region has low effectiveness due to low speed and high pitch

It was further reasoned that if the rotor blades are lengthened the rotational speed would need to reduce and so the ineffective core region would enlarge. If one continued to lengthen the blades (needing further reduction of rotational speed) a much larger proportion of the blade would become ineffective - the outer part contributing most of the lift (or thrust). With little loss in overall lift one therefore could remove the inner part of the blade - affixing the outer part to a ring for support.

If one continues to increase the blade's radius, reducing rotational speed and readjusting the inner ring size a further effect would need consideration - that due to centrifugal forces - requiring further reduction of rotational speed. At this stage effectiveness of the blade to generate lift would reduce, needing redesign or changes in the aerofoil section of the blades, thus causing the ineffective central region to grow. The difference in linear speed from the ring (where the blade is truncated) to the outer tip also would reduce, enabling this part to be of constant or symmetric section.

Continuing this process of reasoning, and reducing rotational speed somewhat to avoid both centrifugal and high speed effects, one can imagine the low speed constant stub wing section of one aspect of the present invention being used to generate an annular region of lift (similar to a group of aeroplanes following each other and flying in formation around a point).

Balloons often adopt a natural non-pressurised form, enabling very light fabric to be used for containment of the lifting gas. Such forms are not well suited to mount thrust units and other system features, since they are delicate and the membrane is not stable enough (due to low pressure). Non-rigid airships use super pressure to stabilise the envelope membrane, enabling other features to be mounted.

An object of the present invention is to make use of pressure stabilised membrane technology for stiffening purposes of such aircraft, where necessary.

A further object of the present invention is to utilise the simplicity, weight, and cost effectiveness of balloon technology with a novel aerodynamic lift system to provide a commercially viable transport aircraft that can operate autonomously.

Also, a further object is to provide an aircraft comprising an envelope inflated with a gas that is lighter than air (thereby to generate aerostatic lift), with an aerodynamic lifting device that does not require movement (translation or rotation) of the aircraft's main body to generate the aerodynamic lift.

According to the present invention there is provided an aircraft comprising an envelope that is inflatable with a lifting gas that is lighter than air and has, at least when inflated, curved upper and lower surfaces, a payload carrying means, and an aerodynamic lifting means operable to generate lift on the envelope by causing a vertical annular flow of air that further induces a flow of air over the respective incident upper or lower curved surface thereby to generate lift.

The vertical annular flow may be upwards or downwards.

Preferably the aerodynamic lifting means comprises a plurality of aerofoil blades mounted for rotation around a periphery of the envelope.

Preferably the aerofoil blades are variable pitch blades, and blade pitch control means are provided for varying the pitch of the blades collectively to effect directional control of the resulting annular air flow.

Preferably thrust control units are attached to the envelope to provide directional thrust to the aircraft.

Ideally the envelope is of circular shape when viewed in plan, and the blades rotate about a vertical centre-line axis of the envelope. Other plan shapes are possible such as, for example an oval, ogival, or elliptical shape, but in these cases means have to be

found to drive the blades around the perimeter of the envelope. One way of doing this would be to mount the one or more blades on interconnected carriages that are around the perimeter by a linear electric motor.

Preferably the envelope is of lenticular shape when viewed in elevation.

The present invention will now be described, by way of example, with reference to the accompanying drawings, in which:-

Figure 1 shows the side view of an aircraft constructed in accordance with the present invention in a high moored configuration;

Figure 2 shows the side view of the aircraft of Figure 1 in an intermediate moored configuration;

Figure 3 shows the side view of the aircraft of Figure 1 in a low (storm) moored configuration;

Figure 4 shows a plan view of the aircraft of Figure 1 (from above);

Figure 5 shows an inverted plan view of the aircraft of Figure 1 (from below);

Figure 6 shows a side view of the aircraft of Figure 1 transporting a pay-load in free flight;

Figure 7 shows in more detail the main under slung working module of the aircraft of Figure 1;

Figure 8 shows schematically a side view of the aircraft of figures 1 to 7 showing one form of aerodynamic lift generator constructed in accordance with the present invention;

Figure 9 shows in greater detail a view taken along line A-A of Figure 8; and

Figure 10 shows in larger scale the detail of the aerodynamic lift generator mechanisms shown in Figures 8 and 9.

Referring to Figures 1 and 6, the aircraft is a hybrid LTA vehicle. It comprises the following main assembly, modular or system features, namely lifter 1, a main under-slung working module 2, rigging 3, lifter management system 4 and a payload suspension plus containment system 5.

The lifter 1 comprises a lifter body 6 comprising a lifting gas containment envelope 6 having upper and lower surfaces that, at least when the envelope 6 is inflated, are of curved profile. The lifter 1 includes thrust unit and aerodynamic lift system configurations 7, 8 respectively. In the drawings the envelope 6 is shown as being of lenticular shape when viewed in elevation, but it could be spherical or other curved body of revolution shape (such as pumpkin).

The lifter body 6 has a large diameter tubular ring 9 that provides a stiff chassis and constitutes a consistent main mounting structure able to hold its shape for the other parts. A similar ring also is utilised by another aircraft that is described in a co-pending British patent application No. 0225483.7. The aircraft described in the co-pending patent application, and which is called a StratRaft, is a lighter than air vehicle suitable for flight in the stratosphere for use as a stratospheric platform for electronic and communications equipment. The aircraft of the present invention incorporates some of the structural features of the StratRaft, but is not arranged specifically to fly in the stratosphere as configured for the purpose of this application. Nonetheless, by adoption of changes described later the aircraft of the present invention also may be configured for stratospheric applications. Where the context permits, the details of the

StratRaft described in the co-pending patent application are incorporated herein by reference thereto.

As for the StratRaft, a secondary means to pressure stabilise the tubular form of the ring 9 will be necessary if it is of non-rigid form. Air may be used for this purpose, if desired, but the lifting gas would help to negate the weight of the ring 9. It is not, however, intended that the ring 9 be the main chamber for lifting gas containment.

The tubular ring 9 also is fitted with regular bulkheads (not shown) that stabilise its form and which are used for attachment of other parts. It also integrates with the Thrust Unit Support Structures 10, provided as hard structures, each with a pylon (not shown) to support the respective thrust units 7. The thrust units 7, however, are mounted at different positions and normally utilised only for lateral translation both in the fore or aft directions and in sideways directions, and for steering (rotational control about the vertical yaw axis) or steadying purposes. In addition, the stiffening ring 9 provides the mounting base for an aerodynamic lift system 8, described later below.

Integration of the tubular ring 9 with the thrust unit hard structure 10 may be by simple clamp ring techniques. The bulkheads also may be of fabric materials and should freely allow the passage of gas (and people) between each cell. The bulkheads also would be used to transmit load from the rigging arrangements 3 that restrain the aerostatic gas lift.

The envelope 6 also comprises an upper envelope assembly 11 and a lower envelope assembly 13. The upper envelope assembly 11 comprises an upper membrane 12 that connects to the upper surface of the stiffening ring 9 at a tangent position (see Figure 9) via a continuous gas tight joint (adhesively bonded or welded). A clamp plate

method (similar to envelope penetration reinforcement clamp rings) also may be used to make the joint, which will be necessary if a rigid stiffening ring is adopted.

The upper envelope assembly 11, which is arranged to provide the larger part of the main chamber for the lifting gas, is subject to moderate gas pressure levels to stabilise its membrane 12. As such it can be made from reasonably lightweight fabric, since it is not a main structure feature (the stiffening ring 9 is used to carry such loads). In addition, the upper membrane 12 can be used to provide the mounting surface for solar energy collector panels (not shown), if desired for power generation purposes. It is envisioned, however, that more conventional motor driven power generation systems would be utilised.

The lower envelope assembly 13 has a membrane 14 that connects to the lower inside surface of the stiffening ring 9 at an approximate (depending on viewing point) radial 5 or 7 o'clock position (when inflated) via a continuous gas tight 'T' joint (see Figure 9). This is not the only position for lower envelope attachment, which depends ultimately on the thrust units' 7 configuration.

The lower envelope 13 is approximately symmetrical to the upper assembly 11 of the lifter body 6 main lifting gas chamber and with a similar curved profile to the upper membrane 12. The difference between the upper and lower assemblies 11, 13 of the envelope 6 resides in their connection position on the stiffening ring 9. In addition, the lower assembly 13 is provided with a ballonet 13(a) for gas expansion accommodation and pressurisation purposes – similar to non-rigid airship envelopes. It also may be manufactured from lighter weight fabric compared with the upper membrane 12, since it is not subject to such high gas pressure as the upper part of the envelope 6, due to gas pressure head effects.

The ballonet 13(a) is a dished membrane for air containment attached concentrically at its outer edge to the inner side of the lower envelope membrane 14 (as part of the lower envelope assembly 13), which (when empty) lies against the membrane 14 but (when filled with air) rises and inverts to an opposite bubble shape (when full).

The upper 11 and lower 13 assemblies together with the main stiffening ring 9 provide an overall essentially lenticular shaped gas containment envelope 6 (the lifter body) that has two chambers, namely :

- the tubular ring (stiffened with high pressure) and
- the main envelope chamber 6 (stiffened with low pressure) between the upper and lower envelope assemblies 11, 13 and closed by the inner wall of the ring 9.

The lifter body 6 therefore has a stiff outer lower shoulder and outer equator rim 9 used to mount other aircraft features. The lenticular form enables overall aircraft height to be reduced (as shown from figure 1 to 2) when moored and provides a low drag solution unaffected by wind direction during flight and whilst moored.

The shape of the lifter body 6 is expected to be constant and it is preferred that it is lenticular when viewed in elevation (as shown in the drawings). Other shapes are possible, including other curves of revolution such as, for example, a profile that results in a sphere. This would affect the joint positions between the membranes 12, 14 and the ring 9, overall height and aspect ratio of the envelope 6, and the placement of the thrust units 7 and aerodynamic lift system 8, but not the overall concept. Final shape of the envelope may, therefore, be decided by the developer. It should be noted, however, that other shapes will also affect the ability of the aerodynamic lift system to

generate adequate lift, since it is an interactive system that uses the presence of the lifter body to generate lift. Other shapes will affect such performance.

The lifter 1 is provided with an aerodynamic vertical lift system 8 as part of the means to carry and transport the payload. The aerodynamic lift system is shown in greater detail in Figures 8 to 10.

Referring to Figures 8 to 10 the aerodynamic lift generator 8 is similar to a very large fan in appearance, and has aerofoil blades 20 (only one of which is shown in Figure 8), equispaced around the circumference of the envelope 6, that rotate around a hub. The blades 20 are stub (low aspect ratio) wings each of which is mounted on a torque tube 21 retained for pivotal movement about its longitudinal axis in a rotatable rigid ring 22 that is able to rotate on rollers 23 held in sleepers 24 that constitute a track way provided on the outer face of the lifter body's stiffening ring 9, which effectively acts as the hub, and, of course, is of exceptionally large diameter.

The upper part of the rigid ring 22 accommodates a plurality of pinion gears 25. There is one pinion gear for each blade 20. Each pinion gear 25 engages with a rack 26 on each torque tube 21, so that rotation of the pinion gear 25 alters the pitch of the blade 20. The pinion gears 25 of each stub wing 20 are interconnected by a flexible torsion shaft (not shown) independently supported by bearings and universal joints around the rigid ring 22 to ensure synchronisation and collective movement of each blade 20. This torsion shaft is driven independently at say 4 equispaced positions around the ring 22 to control the pitch attitude of the stub wing 20.

Aerodynamic lift is expected to be generated in two ways. Firstly, by flow over the rotating blades 20, which will cause a vertical annular draft around the envelope 6.

Secondly, due to secondary effects, by core air flow that is induced to flow with the vertical annular draft, itself caused to flow by the impeller action of the stub wings 20 as they rotate around the lifter body 6. The incident core air flow is forced to move radially outwards by the presence of the envelope 6 over its incident curved surfaces 12 or 14 (depending on flow direction) and then separates from the lifter body on the outwash side, thereby generating aerodynamic lift from the pressure distribution that results on the envelope 6. The direction of the vertical flow and thus lift is determined by the pitch of the blades 20. A significant proportion of the total lift is expected to be due to air flow over the incident curved surface 12, 14 of the envelope 6.

Rotation of the blades 20 may be undertaken in a variety of ways:

- by thrust units mounted on the stub wings 20 or the rigid ring 22
- by an electrical linear motor system between the rigid ring 22 and the fixed sleeper tracks 24,
- pneumatically by an air jet system between the rigid ring 22 and the fixed sleeper tracks 24,
- by a mechanical drive system between the rigid ring 22 and the fixed sleeper tracks 24,
- by jet efflux at the trailing edge of the stub wings 20.

Similar methods for motivation and the track arrangements that could be used in the present invention are used in other industrial applications so do not need any elaboration here. In this respect, the aerodynamic lift system 8 is a new feature for aircraft. - -

The preferred plan form of the envelope 6 is a circular shape because this simplifies the mounting and drive mechanism for the aerodynamic lifter 8. However, it may be possible to make the envelope 6 of an oval, ogival or elliptical shape in plan. In this case, it would be necessary to mount each blade 20 (and it's associated torque tube 21) on a carriage (not shown) that is connected to adjacent carriages around the perimeter of the envelope 6 to form a driven part of a linear electric motor that functions to propel the blades around the periphery of the envelope 6. It may be possible to develop an alternative system similar to a conveyor belt type of drive.

Other methods for such air circulation control to generate aerodynamic lift, such as "blown slot" techniques may be incorporated to augment the aerodynamic lift system 8. In this case the upper and lower membranes 12, 14 may incorporate a plurality of air discharge nozzles from which pressurised air flows issues thereby to induce air to flow radially outwards over the incident upper or lower surface 12, 14 and improve lift in a similar way to that used in so called blown slot or blown wing designs. Similarly it may be possible to generate aerodynamic lift using electro-kinetic lift methods, whereby through the use of electrostatic effects an air circulation flow results over the incident surface 12, 14 that causes aerodynamic lift.

Such methods are interesting, since they do not necessarily involve any moving parts – so might be configured more simply. The methods are new and potentially of great benefit but so far have little accreditation. Whilst such methods may be used to supplement or augment the aerodynamic lift system 8 described above, it may also be possible to replace the aerodynamic lift system 8 with an electro-kinetic system, or a system of air discharge nozzles through which pressurised air issues so as to induce an air flow over the respective incident curved upper or lower surface 12, 14, or with a combination of both electro-kinetic and blown nozzles.

Referring to Figures 1 to 7, the rigging 3 comprises the working module suspension system 15 plus mooring/handling lines 16. The various rigging lines 3 connect at bulkhead positions to the main stiffening ring 9 between the upper 11 and lower 13 envelope joints. These lines 3 can be used early in the aircraft assembly and inflation sequence, enabling in-field build and inflation arrangements without a hangar.

The mooring/handling lines 16 are each of the same long length – to enable haul down against the much greater aerostatic lift from the main chamber (filled with gas to a much greater extent). Also the working module suspension lines 15 are arranged to interconnect directly between the main stiffening ring 9 and the working module 2. They also should have lockable release facilities from the working module 2 so that they can be used for storm mooring purposes as well.

Whilst twelve rigging line 3 positions are shown, this is only illustrative (to show the principle). However, although twelve is a reasonable number (providing redundancy against failures), the actual number of attachments should be decided from a formal analysis – taking account of failure aspects.

The rigging arrangements allow the working module 2 to be moved to one side, as shown from Figure 2 to Figure 3, further allowing the lifter 1 to be held near to the ground (without affecting lower end features). Ability to hold the lifter close to the ground in a stationary manner and permit construction without a hangar are significant benefits compared with current airship practices. These aspects will aid deployment of the aircraft over wide regions, reduce maintenance costs plus difficulties and enable severe storm conditions to be endured. The arrangements also facilitate

decommissioning for transport to another site or back to production facilities for repair work.

The working module itself 2 is supported via an independent suspension system 15 from the main stiffening ring 9, obviating effects due to lifting gas expansion and contraction. Suspension lines 15, in plan similar to the spokes of a bicycle wheel, extend down from the main stiffening ring's bulkhead connection points directly to releasable attachment parts (not shown) on the upper edge of the working module 2. Conduit may also follow these routes (although a centralised route discussed latter is recommended) to provide necessary power, signalling and control over the upper mounted systems – guaranteeing that line lengths can be maintained.

Rigging line parts 3 may be made using existing materials and parts that generally are stock items, although some parts (such as attachment brackets) may need to be developed to suit. Careful attention to the selection of materials and the detail arrangements will be necessary to avoid damage due to lightning strike attachments. Nonetheless, development and construction would follow normal aircraft practices, so do not need elaborating in any detail here. The particular arrangements will be for the developer to undertake/decide.

Whilst suspension systems in many other applications use similar parts, the particular arrangement here is a new concept, enabling independent support from the main stiffening ring. Vertical load from the working module 2 is carried directly to the stiffening ring. Each suspension line applies an inward load on the stiffening ring 9 that must be reacted. The load initially is carried by the stiffening ring's bulkheads, which in turn transfers the load in shear and tension to the stiffening ring tube. The radial loads cause compression across the section of the stiffening ring that resists the line forces.

As a flexible fabric structure, this compression is resisted through the stiffening effect of its pressurisation, thus enabling the support without significant change to the overall geometry. Vertical load from the suspension lines is carried by the aerostatic and aerodynamic lift methods of the lifter 1.

The working module 2, with its payload and necessary aircraft systems will be very heavy and is under slung at a very low position from the lifter 1. Most of the weight will result from ballast (if there is no payload), to counteract the gas lift (buoyancy), or result from a combination of ballast and payload. This mass should provide strong pendulum stability to keep the essentially lenticular lifter body 6 from behaving aerodynamically in an unstable manner.

The handling/mooring lines 16 enable the aircraft to be restrained at its full height (as shown in Figure 1). This normally only would be prior to a launch or after capture. The lines 16 would be used with winch gear to haul down or let up the lifter 1 against buoyancy to heights where the suspension lines 15 may be connected/disconnected (as shown in Figure 2) or take up load (as shown in Figure 1). When properly secured by all of the mooring lines (as shown in Figure 2) the working module 2 should be carefully moved to one side – out of the way. The lifter should then be hauled right down to its lowest level and additionally secured by the suspension lines (as shown in Figure 3) to hold it safely against adverse weather.

Capture (recovery action, when the aircraft is first caught by the ground crew and connected to ground restraint facilities) and Launch (the release action, when the aircraft is finally let go by the ground crew from its last restraint point) are facilitated by a single line 17 below the working module 2. The line is used to pull the floating aircraft down to the ground and then tie-off to hold it in position. This action possibly can be

undertaken using manpower effort assisted by the aircraft thrust units and aerodynamic lift system. It will require a central mooring site anchor fitted with a ring to pass the cable through and a tie-off point to one side (not below the working module), which also can be a ring on a ground anchor. Once captured, the handling/mooring lines 16 would be connected followed by haul down of the lifter 1, as described above. When restrained by the handling/mooring lines 16 as shown in Figure 2 the recovery/release line 17 may be disconnected from the anchors and the working module suspension lines disconnected to permit movement of the working module to its side parking position.

If needed, for whatever reason, the recovery/release line 17 also may be used to move the aircraft to a new position using a floating technique, where the aircraft is connected to a heavy surface mover (tug or tow vehicle) then ballasted to a light condition (where buoyancy exceeds gross weight) to maintain line tension and finally towed to its new position. This could be necessary if the aircraft is unable to return to its ground station for recovery purposes. The handling/mooring lines 16 also may be used for this purpose with additional surface movers to provide restraint during the transit.

The recovery/release line 17 also may be used as an alternative or under abnormal circumstances, as a mooring line. In this case a longer retractable line would be connected, enabling the aircraft to be let up under static light conditions to a higher position (as a tethered aerostat) where it can then freely ride the weather circumstances without excessive line loads.

The recovery/release line 17 also must be able to discharge static electricity from the aircraft to ground. Procedures will be necessary during capture or launch that personnel do not handle any line 15, 16 or 17 until static discharge has occurred. This

will necessitate the line touching the ground before the ground crew recover the line. The lines also may be used as part of a lightning protection and discharge system. The particular arrangements for lightning strike protection will need specialist help to develop the method – so is not covered by this outline (other than to introduce the concept and state that it is necessary).

The above description for launch and capture is similar to the StratRaft and may be utilised as desired. The aircraft, however, may utilise additional or alternative automated facilities in these processes to help overcome problems due to shear size and the resulting high forces that must be managed. The aircraft, by virtue of its payload carriage method, already will have a strong line beneath the working module suitable for such restraint purposes – normally used to carry the payload as an under-slung package. This line also may be extendable via a winch system affixed below the working module and be provided with a lower hook. Since during launch or capture the aircraft would not be transporting a payload, this line may be used for the recovery/release action in a manner similar to that described above but simply connected to a central restraint point. The aircraft under its own power may then draw itself down or let itself up using the winch facility to a position that is safe for ground crew personnel to connect/disconnect the line.

If desired and to avoid danger to ground personnel working below the aircraft, this last line connection/disconnection process to the central mooring site restraint point also may be automated. If, instead of a simple hook at the lower end of the line an automated calliper jaw mechanism is provided, then the pilot could utilise this to undertake the operation unaided. Precise control of the aircraft and visual plus sensing systems would be necessary to assist the pilot in this operation. The automated system also would be useful for pickup and delivery of pre-packaged payloads.

Alternatively, the automated capture mechanism could be a facility installed and operated on the ground at the central mooring site position. A simple pendant fitting on the end of the line would then be all that was necessary. The mechanical arrangements utilised would be for the developer to decide.

Referring to figure 7, the working module 2 is the main housing for the aircraft's primary systems, such as: ballast 30, pressurisation 31, electrical 32, control 33, avionics 34, fire detection and suppression 35, environmental control 36, auxiliary power 37 and miscellaneous equipment 38. These are all typical of airship and other aircraft installations, so do not need elaborating in great detail here. It is expected that existing technology would be adapted and used to fulfil the needs and this will be for the developer to undertake/decide.

The working module also provides environmentally controlled facilities for the crew. It is envisioned that the working module will comprise three main sub-modules, as follows:

- systems capsule 40,
- pilots' command and control capsule or cockpit 41,
- lifter systems' module 42.

The systems capsule 40 is the main vessel for containment of the aircraft working systems 30 to 38 and provides housing for crew furnishings, equipment and essential facilities. It would have two main levels:

- an upper floor region for the mainly dry systems and personnel facilities,
- A large lower tank level for necessary ballast water containment.

It is envisioned to be constructed as a vertical cylinder with dished upper and lower end caps, as a pressure vessel. It would be provided with a mid level floor, upper ceiling, upper level windows and doors, lower level integral water tanks plus central vertical access shaft and interface positions suitably reinforced/stiffened as necessary to suit the purpose. It is expected that it would need to be pressurised to a low level to provide the necessary environment for the systems and personnel aboard. Its development and construction would follow normal aircraft practices, so do not need elaborating in any detail here. The particular arrangements will be for the developer to undertake/decide.

The cockpit 41 is an under-slung turret below the systems capsule 40, which provides the housing for the pilots plus their controls, instruments, displays, etc. It also is envisioned to be constructed as a vertical cylinder with a dished bottom cap, as a pressure vessel. It would be provided with a floor, windows and door suitably reinforced/stiffened as necessary to suit the purpose. Its development and construction would follow normal aircraft practices, so do not need elaborating in any detail here. The particular arrangements will be for the developer to undertake/decide.

The lifter systems module 42 is a unit that sits atop the systems capsule 40 to house the blowers and valves plus other systems necessary for pressurisation and management of the lifter as an inflated structure. These systems are typical of aerostat installations, so do not need elaborating in any detail here. The particular arrangements will be for the developer to undertake/decide.

The lifter management system 4, comprises the systems in the lifter systems module 42 together with a fabric umbilical trunk 43 between the lifter systems module 42 and the lower envelope surface 13 plus conduit lines from the lifter systems module to their respective lifter positions and associated passages (not shown) in the lifter.

The fabric umbilical trunk 43 provides for the passage of air (contained in the ballonet compartment) to regulate the main envelope chamber super pressure. The trunk also should be provided with means for maintenance personnel to use it as a passage for access into the lifter's ballonet 13(a) compartment.

It should be noted that normally aerostat pressurisation and management systems are mounted directly below on the underbelly of the respective aerostats that they serve and that the air valves, which release air from the ballonet, are mounted on the lower envelope. Grouping them together in the lifter systems module 42 atop the systems capsule 40 and using the fabric trunk 43 is a new method that facilitates maintenance without the need for high reach equipment. Indeed, access to the lifter systems module 42 and subsequent access to the lifter 1 plus its systems and parts via the fabric trunk 43 and subsequent air passages is possible during flight if the developer chooses to adopt such arrangements.

The fabric trunk 43 plus sealable air passages (not shown) from the ballonet 13(a) compartment to the stiffening ring 9 would also be utilised as the main conduit route for electrical, control, signalling and other lines. In this way inspection, maintenance or repair may be attended to at any time.

Self contained power units 44 should be installed on top of the systems capsule 40 to provide power mainly for the working module systems and the payload package 5. A minimum of two independent units, each able to provide the necessary power is desirable for redundancy and to facilitate maintenance.

Since the working module 2 could be damaged when the aircraft returns to the ground, fenders 45 would be necessary. These could be obviated if the operator is confident enough, but this is not recommended. Various types of fender may be used, such as: bumper, pontoons, wheeled shock absorber legs, skids, etc, to suit the operational circumstances. The author's choice is a sprung skid arrangement at three positions around the working module that use a large rotating dish as the skid (similar to some castors) and acting as legs to support the working module.

For horizontal and yaw control of the aircraft, ducted propeller thrust units 7 driven by motors behind the propeller are used. The propeller itself should have variable blade pitch angle control to enable varying amounts of thrust both forward and rearwards to be developed. This will be necessary to provide precise control, particularly during launch or capture and payload pickup or set down.

Power for/from the thrust unit motors either may be drawn from electrical installations housed in the thrust unit support structure 10, as discussed above, or (as an engine with generators) may be supplied to the power distribution system. Additional small and self contained auxiliary power units 44 may also be installed in the thrust unit support structures, to boost or provide power for the aerodynamic lift system.

Four (although a minimum of 2 may be acceptable) thrust units 7 are shown in the figures, suspended below the stiffening ring, which are needed for yaw and horizontal translation control. The units are aligned tangentially with the ring. Further units could be installed (improving failsafe aspects). This however, does not alter the concept and will be for the developer to decide. These arrangements are similar to those already developed for other uses. The particular arrangements will be for the developer to undertake/decide.

The thrust units also may be provided with a vector system to rotate the duct for alignment of the thrust, as desired, although not needed with this configuration. Several airships and other aircraft have used such mechanisms for similar purposes, so this does not need to be elaborated. The particular arrangements will be for the developer to undertake/decide.

As the aircraft translates horizontally it is possible that the lift generated would be unequal, tending to cause roll and or (due to gyroscopic effects) pitch. If this is a problem then either the pitch control mechanism will need to operate in a way that compensates adequately (similar to helicopter blade controls) or the thrust units 7 used to compensate (from appropriate vectored thrust). With the strong pendulum effect of the weight below the lift, tending to keep the aircraft upright, it is thought that this will be unnecessary.

In addition to thrust and lift control other controls will be necessary, such as:

- ballast dump – to reduce weight,
- helium valves – to reduce aerostatic lift,
- envelope rip or holing system – to destroy aerostatic lift.

These are standard airship features, the particular arrangements of which will be for the developer to undertake/decide.

Navigation lighting 46 and a transponder (not shown) will also be necessary, to comply with the Air Navigation Order. These are mandatory, the particular arrangements of which will be for the developer to undertake/decide.

The payload suspension and containment system 5, effectively is a separate packaging method (not part of the aircraft) that enables efficient transport of the payload as an under slung load beneath the working module. A single line 17, discussed previously, may be used for this purpose that connects via an automated mechanism to the top of the payload transport jacket 47. The mechanism would be the same as that described previously at the mooring site centre for Launch/Capture.

The payload transport jacket 47 is a spherical fabric pressure stabilised envelope, similar to a balloon (inflated and stabilised with air), that completely enshrouds the payload within it. Rigid carriage structure (not shown) located at the top, within the transport jacket, would support both the payload and the transport jacket plus provide the necessary interface for connection to the aircraft's lower line 17. Systems to pressure stabilise the spherical envelope in a manner similar to those used for non-rigid airship envelopes also would be provided on the carriage structure and be powered via an umbilical line from the aircraft (not shown). Large ground blowers would be used to initially and rapidly inflate the jacket with air, its own system being used just to maintain levels for pressurisation after inflation.

A variety of methods familiar to those in the heavy lift industry may be used to support and restrain the payload from the rigid carriage structure, so do not need to be elaborated here. Also, the payload is an unknown quantity that may need particular methods for its support. Whatever, these methods will need to be arranged to suit the payload and be provided in a way that complies with aircraft requirements plus the operating conditions of flight. The particular arrangements adopted will be for the developer to undertake/decide.

It is envisioned that the support arrangement and transport jacket would be prepared and be inflated beforehand, ready for the aircraft to transport the package. Crane facilities, high reach facilities and steadying methods would be necessary for these pre-arrangements. If the jacket is provided in two hemispherical halves (upper and lower) with zipped seals and lacing methods to hold the hemispheres together then the crane may be used to:

1. lift the payload into the lower hemisphere (spread on the ground);
2. lift the upper hemisphere with the rigid carriage over the payload and hold it whilst the payload support arrangements are connected and rigged (tensioned);
3. lift and hold the rigged payload as necessary whilst the hemispheres are joined, sealed and then the jacket inflated;
4. transfer support to temporary rigs and steadying facilities positioned inside, around and below the jacket, as necessary.

The payloads, as mentioned before, are an unknown quantity that will vary in size, weight and form. The transport jacket will thus standardise the package to be transported, enabling flight characteristics that are known and will not vary. If unsteady characteristics arise from the spherical form then aerodynamic modifications may be adopted, as necessary, to provide a commercially re-useable and safe jacket system. Such modifications, however, do not change the principle of the method and will be for the developer to undertake.

It is suggested that several differently sized transport jackets be developed to cover the range of circumstances that will be necessary in such transport operations. Some operations may also require transport without the jacket and these will need special consideration, which the developer should undertake.

The aircraft described above in relation to Figures 1 to 10 is intended for use at normal flight altitudes. In a further embodiment of the present invention, the aircraft may be designed to operate in the stratosphere. The main problem that the aircraft has to overcome for stratospheric applications is expansion or contraction of the lifting gas through the respective ascent or decent stages. In the case of the aircraft of the present invention, the main gas containment chamber 6 would be provided with a ballonet 13(a) of 100% capacity compared with the lifting gas chamber 6, and associated valves and blowers. Instead of being attached to the lower envelope 13, the ballonet 13(a) would be provided as a dished diaphragm that is attached and extends diametrically across the ring 9 at the inner centre position of the main ring 9. The ballonet 13(a) should drape against the lower membrane 14 when empty and fill to fit against the upper membrane 12 when the ballonet 13(a) is full. In this way a wide range of altitudes into the stratosphere may be flown. The 100% ballonet 13(a) also would aid initial inflation, since this may be used to stabilise the Lifter body shape before the Lifting gas is introduced

CLAIMS

1. An aircraft comprising an envelope that is inflatable with a lifting gas that is lighter than air and has, at least when inflated, curved upper and lower surfaces, a payload carrying means, and an aerodynamic lifting means operable to generate lift on the envelope by causing a vertical annular flow of air that further induces a flow of air over the respective incident curved upper or lower surface.

2. An aircraft according to claim 1 wherein the aerodynamic lifting means comprises a plurality of aerofoil blades mounted for rotation around a periphery of the envelope.

3. An aircraft according to claim 2, wherein the aerofoil blades are variable pitch blades, and blade pitch control means are provided for varying the pitch of the blades collectively to effect directional control of the resulting annular air flow.

4. An aircraft according to any one of claims 1 to 3, wherein thrust control units are attached to the envelope to provide directional thrust to the aircraft.

5. An aircraft according to any one of the preceding claims wherein the plan shape for the envelope is selected from a circular, oval, ogival or elliptical shape.

6. An aircraft according to claim 5, wherein the envelope is of circular shape when viewed in plan and the blades rotate about a vertical centre-line axis of the envelope.

7. An aircraft according to claim 5 or claim 6 wherein the envelope is of a lenticular shape when viewed in elevation.

8. An aircraft according to any one of the preceding Claims wherein the aerodynamic lift generator comprises a plurality of aerofoil blades equispaced around the perimeter of the envelope that rotate around the envelope.

9. An aircraft according to claim 8 wherein each of the blades is a low aspect ratio wing and is mounted on a torque tube retained for pivotal movement about its longitudinal axis in a rotatable rigid ring.

10. An aircraft according to claim 9 wherein the rigid ring is able to rotate on rollers held in sleepers that constitute a track way provided on the outer face of the stiffening ring of the envelope.

11. An aircraft according to Claim 9 or Claim 10 wherein the rigid ring accommodates a plurality of pinion gears, there being a pinion gear for each blade, and each blade is provided with a rack with which one of the pinion gears engages, so that rotation of the pinion gear 25 alters the pitch of the blade 20.

12. An aircraft according to Claim 11 wherein the pinion gears are interconnected by a flexible torsion shaft that is supported by bearings and universal joints around the rigid ring 22 to ensure synchronisation and collective movement of the pitch of the blades when the torsion shaft is rotated.

13. An aircraft according to claim 12 wherein the torsion shaft is driven at equispaced positions around the ring 22.

14. An aircraft according to any one of claims 8 to 13 wherein each blade and an associated torque tube is mounted on a carriage that is connected to adjacent carriages around the perimeter of the envelope to form a driven part of a linear electric motor that functions to propel the blades around the periphery of the envelope.

15. An aircraft according to any one of claims 1 to 7 wherein the aerodynamic generator comprises an electro-kinetic system in which air circulation over the respective incident curved upper or lower surfaces is created by electrostatic effects.

16. An aircraft according to any one of claims 1 to 7 wherein the aerodynamic lift generator comprises a plurality of air discharge nozzles through which pressurised air issues and induces air flow over the respective incident upper or lower surface of the envelope.

17. An aircraft according to any one of the preceding Claims wherein additional means are provided to induce air flow over the respective incident upper or lower surface of the envelope.

ABSTRACT

An aircraft comprising an envelope (6) that is inflatable with a lifting gas that is lighter than air that, at least when inflated has curved upper and lower surfaces. The aircraft has a payload carrying means (5), and an aerodynamic lifting means (8) for creating a vertical annular flow of air that induces a flow of air over the respective upper or lower surface (12, 14) of the envelope (6.). One form of aerodynamic generator (8) comprises a plurality of aerofoil blades (20) mounted for rotation around a periphery of the envelope (6).

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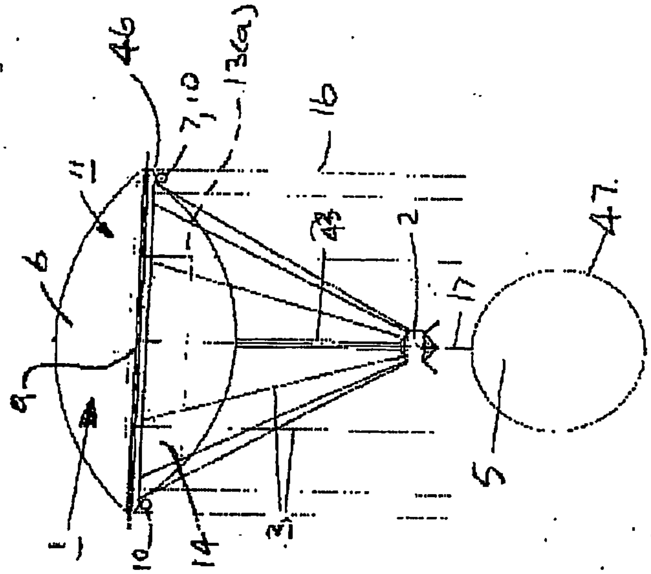


FIG 6

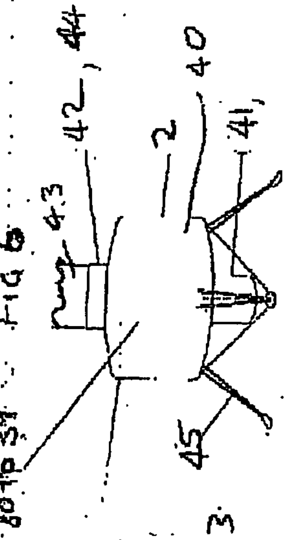


FIG 7

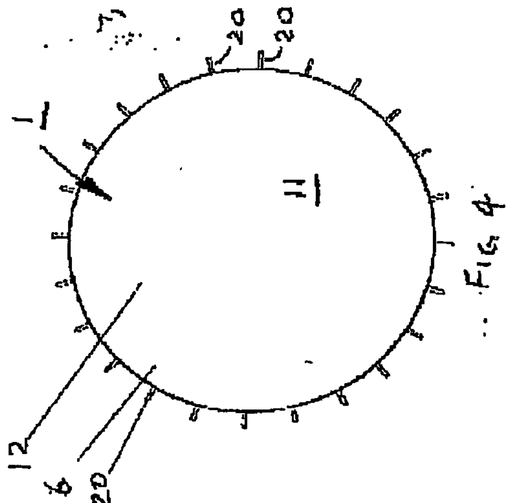


FIG 4

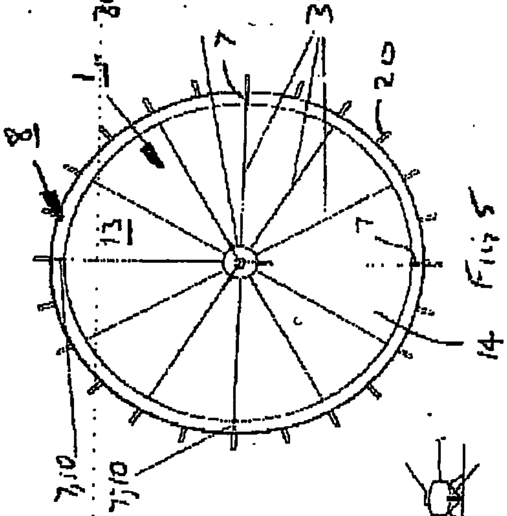


FIG 5

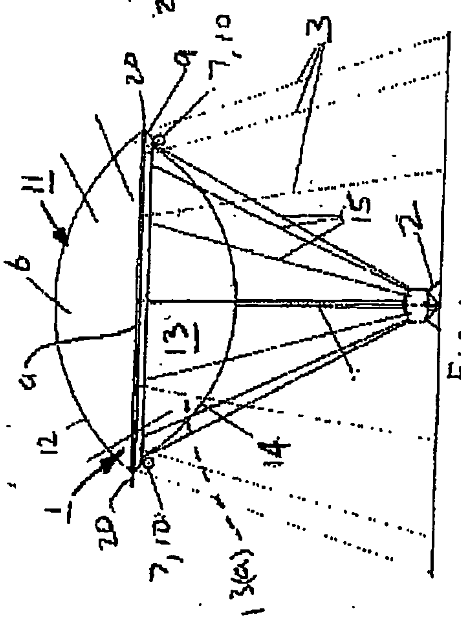
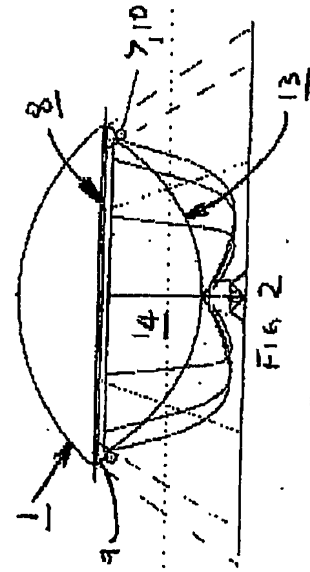


FIG 1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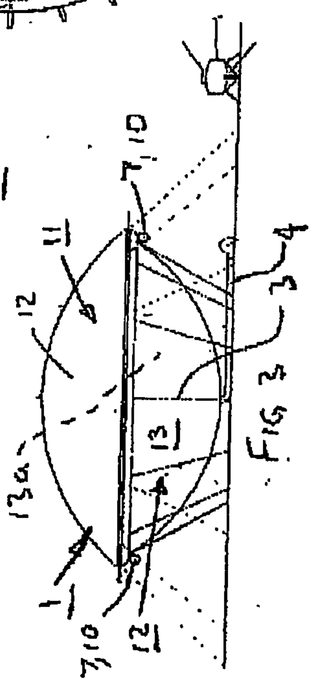
FIG 3

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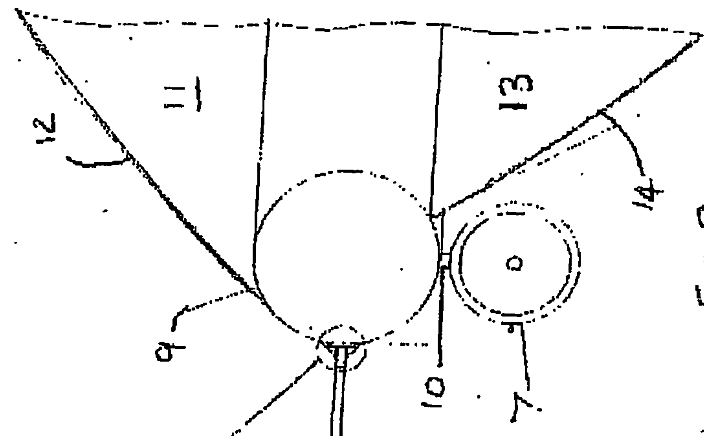

FIG 9

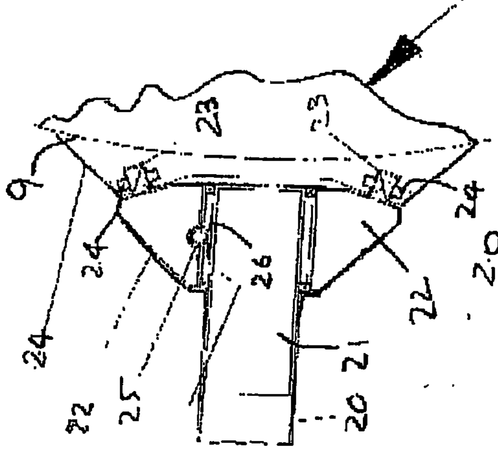

FIG 10

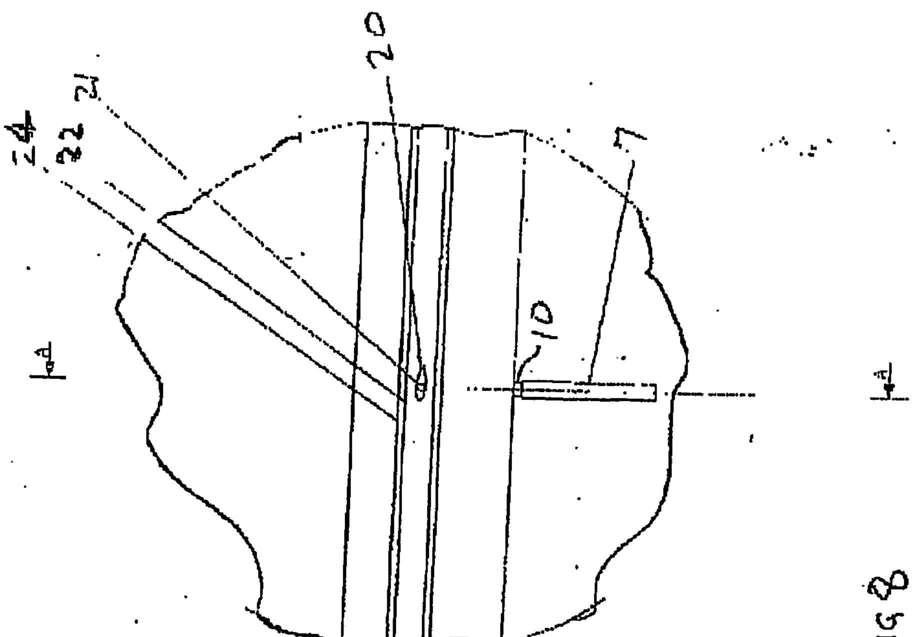

FIG 8